

Method and Apparatus for Dissipating Heat from an Electronic Device

Technical Field of the Invention

The present invention relates generally to the field of electronic devices and, in particular, the present invention relates to thermal management of electronic devices.

Background

Electronic devices dissipate heat during operation. Thermal management refers to the ability to keep temperature-sensitive elements in an electronic device within a prescribed operating temperature. Thermal management has evolved to address the increased temperatures created within such electronic devices as a result of increased processing speed/power of the electronic devices. Historically, electronic devices were cooled by a natural convection thermal management technique. That is, the cases or packaging of these prior art electronic devices were designed with openings (e.g., slots) strategically located to allow warm air to escape and cooler air to be drawn in.

However, with the advent of high performance processors such as the Intel Itanium® processor, electronic devices have required more innovative thermal management. For example, in the last several years processing speeds of computer systems have climbed from 25 MHZ to over 1000 MHZ. Each of these increases in processing speed and power generally carry with it a "cost" of increased heat dissipation. Corresponding improvements in thermal management technology accompanied, out of necessity, such technological improvements. Natural convection was no longer sufficient to provide proper thermal management.

Several methods have been employed for cooling high performance electronic devices such as processors. A common method of cooling such a processor is by the use of a fan heat sink. Figure 1A is a diagram of a prior art fan heat sink 100. As shown in Figure 1A, an axial fan 102 is attached by a fan holder 104 to a heat sink 106 atop a processor. The fan heat sink 100 blows air across the

heat sink 106 to remove the heat dissipated by the processor. To date, the best fan heat sinks are not thermally efficient enough to cool the new higher powered processors. One reason that previous fan heat sinks are not thermally efficient is that the fan forces air down on the processor. One problem with a fan that is positioned atop a heat sink, such as in Figure 1A, is that the fan is too closely located to the fins of the heat sink to generate fully developed air flow. There is a dead space in the air flow which is caused by the fan hub. A fan heat sink such as the fan heat sink shown in Figure 1A is not capable of providing fully developed air flow.

Another approach to cooling high performance processors is the use of passive heat sinks in combination with an axial system fan. One of the problems with the use of a large system fan is blowby. As used herein, the term "blowby" refers to air that is moved by a fan, but does not pass through the fins of a heat sink or over the electronic component itself. For example, when a large system fan is used in conjunction with a heat sink to cool an electronic component, a large percentage of the air moved by the system fan does not go through the heat sink. As a result, large system fans are not an efficient thermal solution for cooling a specific electronic component. Furthermore, some of these new high performance systems require multiple fans to maintain proper operating temperatures. However, the additional fans necessary for previous forced-air cooling systems result not only in an added expense for manufacturers of such electronic devices, but are often bulky and require an inordinate amount of real estate within the chassis. Another problem with the use of multiple system fans is the noise generated by the fans.

In recent years, power dissipation from components in a computer system chassis has increased in small increments for most computer system components except for processors. Figure 1B is a bar graph comparing the power dissipation for various computer system components designed in 1999 and 2000. As shown in Figure 1B, power dissipation for hard drives, memory, and chipsets designed in 2000 increased by only a few watts compared to similar components designed in 1999. Yet, even for computer systems designed in 2000, the power dissipation for

each of the following is still under 20 Watts: hard drives, memory, chipsets and add-in cards. However, the power dissipated by a high performance processor has nearly doubled between 1999 and 2000 (as indicated by the arrow 108 in Figure 1B). For example, in 1999 the power dissipation for a processor was generally between 30 and 40 watts. However, the power dissipation for some high performance processors currently being designed is as much as 70 watts. As shown in Figure 1B, the power dissipation from processors has increased by about 30 watts in a one year period. Furthermore, it is anticipated that in future years the power dissipation of processors will increase even more dramatically.

10 The cooling systems currently being used, such as fan heat sinks and large system fans as described above, are not sufficient to effectively cool such high performance processors. What is needed is a thermal solution to provide high performance cooling for particular electronic components with disproportionately higher power dissipation.

15 For these and other reasons, there is a need for a heat dissipation device to efficiently dissipate the heat generated by high performance electronic devices.

Brief Description of the Drawings

Figure 1A is a perspective view of a prior art fan heat sink.

20 Figure 1B is a bar graph comparing the power dissipation for various computer system components designed in 1999 and 2000.

Figure 2A is a perspective view of one embodiment of an apparatus for dissipating heat from an electronic device.

25 Figure 2B is an exploded view of the embodiment of the apparatus shown in Figure 2A.

Figure 3 is a perspective view of cooling attachments comprising a kit of parts for an electronic component cooling system according to one embodiment of the invention.

30 Figures 4A and 4B are side views of two example configurations of the housing shown in Figures 2A and 2B.

Figure 5A is a perspective view of an example embodiment of an apparatus for cooling an electronic device.

Figure 5B is an exploded view of the apparatus shown in Figure 5A.

Figure 6A is a perspective view of an alternate embodiment of an apparatus
5 which utilizes redundant fans for cooling an electronic device.

Figure 6B is an exploded view of the apparatus shown in Figure 6A.

Figure 7A is a perspective view of an alternate embodiment of an apparatus which utilizes a system fan for cooling an electronic device.

Figure 7B is an exploded view of the apparatus shown in Figure 7A.

10 Figure 8 is a perspective view of an example embodiment of an apparatus with two electronic components in an in-line configuration.

Figure 9 is a perspective view of an alternate embodiment of the apparatus in Figure 8.

15 Figure 10 is a perspective view of a dual processor configuration in which each processor housing is coupled to an air duct for fresh air intake.

Detailed Description

In the following detailed description of the invention reference is made to the accompanying drawings which form a part hereof, and in which is shown, by way of
20 illustration, specific embodiments in which the invention may be practiced. In the drawings, like numerals describe substantially similar components throughout the several views. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized, and structural, logical, and electrical changes may be made, without departing from the
25 scope of the present invention.

A method and apparatus for dissipating heat from an electronic device is described. The method and apparatus efficiently dissipates the heat generated by high performance electronic devices.

substantially eliminates blowby. The example embodiments of the apparatus for dissipating heat shown in Figures 2A and 2B (as well as in Figures 3 -10) ensure that nearly all of the air that a fan is capable of moving is channeled through the fins of a heat sink. According to embodiments of the present invention, there is no place
5 else for the air being moved by the fan to go, but through the fins of a heat sink. In contrast, previous systems with large system fans create a large amount of airflow, but much of that airflow does not flow through the heat sink's fins. Thus, the present system substantially eliminates blowby and, as a result, increases the thermal efficiency of the fan used to cool the electronic device. Furthermore,
10 because the system uses a small fan, this system is much quieter acoustically.

Figure 3 is a perspective view of interchangeable cooling attachments comprising a kit of parts for an electronic component cooling system. In one embodiment, the kit of parts comprises a heat sink housing 314 and one or more interchangeable cooling attachments 302, 304, 306, 308, 310, 312, 316, 318, 320,
15 and 322 to provide a scalable and universally applied thermal solution for high heat generating electronic components. In one embodiment, the interchangeable cooling attachments 302, 304, 306, 308, 310, 312, 316, 318, 320, and 322 are molded pieces of plastic.

In one embodiment, the one or more cooling attachments include one or
20 more housing air duct adapters 302, 304, 306, an air inlet chassis adapter 308, one or more housing fan adapters 310, 312, a housing connector 316, one or more chassis fan adapters 318, 320, and a splitter 322. The housing air duct adapters 302, 304, 306 are adapted to attach to the housing 314 and to receive an air duct such as an air duct in the shape of a hose (as shown in Figures 5A and 5B). The first housing air
25 duct adapter 302 is adapted to receive the air duct at about a 45 degree angle. The second housing air duct adapter 304 is adapted to receive the air duct at about a 90 degree angle. The third housing air duct adapter 306 is not angled.

The air inlet chassis adapter 308 is adapted to be secured to an external vent on the chassis. The air inlet chassis adapter 308 may be secured in any manner. In
30 one example the air inlet chassis adapter 308 is secured with an adhesive.

The fan housing adapters 310, 312 are adapted to attach to a heat sink and to receive a fan. The first fan housing adapter 310 is an extended holder that positions the fan at a distance from the heat sink that achieves fully developed air flow (as shown in Figure 4A). The second fan housing adapter 312 is a contracted fan holder
5 that positions the fan closer to the heat sink than the first fan housing adapter 310 (as shown in Figure 4B).

The housing connector 316 is adapted to create a bridge between two housings 314 when cooling multiple electronic devices positioned in an in-line configuration (such as shown in Figure 8).

10 The chassis fan adapters 318, 320 are adapted to be secured to an external vent on the chassis and to be coupled to an air duct. A single chassis fan adapter 318 allows air from a single air duct to vent outside the chassis. A dual chassis fan adapter 320 allows air from two air ducts to vent outside the chassis. In an alternate embodiment, the chassis fan adapters 318, 320 generate a flow of air from outside
15 the chassis into the chassis and the electronic device cooling system.

The splitter 322 is adapted to couple a single air duct to dual air ducts.

In one embodiment, the various cooling attachments 302, 304, 306, 308, 310, 312, 316, 318, 320, 322 can be attached to the housing 314 to provide a multitude of thermal solutions. The housing 314 may be shaped to fit over any size
20 or shape heat sink.

A kit of parts for an electronic component cooling system may be comprised of any combination of one or more housings 314 and the interchangeable cooling attachments 302, 304, 306, 308, 310, 312, 316, 318, 320, 322 shown in Figure 3. Furthermore, such a kit of parts is not limited to the interchangeable cooling
25 attachments shown in Figure 3. For example, the kit of parts may also comprise one or more air ducts. In one embodiment, the air ducts are in the form of a hose and have a diameter to match the diameter of the housing air duct adapters 302, 304, 306. In another example, the kit of parts further comprises a second housing 314 which is adapted to receive an air intake duct from the top of the housing. In this

case the house has an opening on top for an air duct. An example embodiment of a housing with a top entry opening is shown in Figures 6A and 6B.

Figure 4A is a side view of a housing 400 such as the housing shown in Figures 2A and 2B. The housing includes an extended fan holder 402. The
5 extended fan holder may be a separate part that attaches to the housing. Alternatively, the housing 400 is manufactured as a single part including the extended fan holder 402. When the extended fan holder 402 is used in an apparatus for cooling an electronic device, the fan which is held by the extended fan holder 402 achieves fully developed air flow. When using the extended fan holder 402, it
10 is possible to adequately cool an electronic device at slower speeds because the fan is able to achieve fully developed air flow. The extended fan holder 402 positions the fan at a distance from a heat sink enclosed by the housing 400 that is about equal to the diameter of the fan.

Figure 4B is a side view of an alternate embodiment of the housing 400
15 shown in Figure 4A. As shown in Figure 4B, the housing 400 includes a contracted fan holder 404. Like the extended fan holder shown in Figure 4A, the contracted fan holder 404 may be a separate part that attaches to the housing or the contracted fan holder 404 may be formed as part of the housing. The contracted fan holder positions the fan at a distance from a heat sink enclosed by the housing 400 that is
20 less than the diameter of the fan.

In one embodiment, an apparatus for dissipating heat from an electronic device is configured with either an extended fan holder according to Figure 4A or a contracted fan holder according to Figure 4B based on the requirements of the particular thermal situation and the space available in a computer system chassis. In
25 the example embodiment shown in Figure 4A, the extended fan holder 402 is 2.22 inches long and the total length of the housing with the extended fan holder 402 is 6.42 inches. In the example embodiment shown in Figure 4B, the contracted fan holder 404 is one-half inch shorter than the extended fan holder 402 in Figure 4A. The contracted fan holder 404 is 1.72 inches long and the total length of the housing
30 with the contracted fan holder 404 is 5.92 inches. Thus, use of the extended fan

holder 402 takes up more space on a circuit board in a chassis and use of the contracted fan holder 404 requires less space on the circuit board in a chassis.

In one embodiment, a system integrator selects either an extended fan holder or a contracted fan holder from a kit of parts. The fan holder selected depends on
5 the configuration of the circuit board and the space available around the electronic device to be cooled. In an alternate embodiment, a kit of parts such as in Figure 3 includes an adjustable fan holder. When the apparatus for cooling an electronic device is assembled, the adjustable fan holder is adjusted to function as either an extended fan holder or a contracted fan holder based on space available around the
10 electronic device to be cooled.

Figures 5-10 illustrate various configurations of housings and interchangeable cooling attachments from the kit of parts shown in Figure 3. The invention is not limited to the configurations shown in Figures 5-10. Alternate embodiments are contemplated having the interchangeable cooling attachments and
15 one or more housings arranged in a multitude of configurations.

Figure 5A is a perspective view of an example embodiment of an apparatus for cooling an electronic device. In one embodiment, the apparatus 500 shown in Figure 5A comprises a housing 502, a fan 504, and an air duct 506. The housing 502 is adapted to be closely fitted to a heat sink. The housing 502 contains and
20 guides air movement through the plurality of fins of a heat sink. The air moving device 504 is coupled to a first end of the housing 502. In one embodiment, the air moving device pulls air through the enclosure created by the housing and exhausts the air into a chassis of a computer system. The air duct 506 directs air external to the chassis to the housing 502. In one embodiment, the cool air intake is any
25 opening to the exterior of the chassis. The arrows in Figure 5A indicate that air enters the apparatus 500 through the air duct 506 and exists the apparatus 500 through the fan 504. By pulling air from the exterior of the chassis through the enclosure created by the housing 502, unheated air passes over the electronic device and through the fins of the heat sink. In the embodiment, the air duct 506 and the

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housing 502 channel air through the fins of the housing in a manner that substantially reduces blowby.

Figure 5B is an exploded view of one embodiment of the apparatus shown in Figure 5A. As shown in Figure 5B, the apparatus for cooling an electronic device 5 520 is comprised of a housing 522 and various cooling attachments selected from a kit of parts such as the kit of parts shown in Figure 3. The various cooling attachments that are assembled to form the apparatus 520 include an air inlet chassis adapter 524, an air duct 526, a housing air duct adapter 528, a housing fan adapter 530, and a fan 532.

10 The air inlet chassis adapter 524 is coupled to an opening in the chassis and to the air duct 526. The air duct 526 is also coupled to the housing air duct adapter 528. The housing air duct adapter 528 is coupled to the housing 522. The housing 522 is coupled to the housing fan adapter 530 and the housing fan adapter 530 holds the fan 532. The housing fan adapter 530 attaches to the housing 522 at the end 15 opposite of the housing air duct adapter 528.

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In an example embodiment, the air duct 526 may be metal or plastic. The air duct 526 may also be rigid or flexible. For example, in one embodiment the air duct 526 takes the form of a flexible plastic hose. In another embodiment, such a flexible hose is also expandable. For example, the flexible is molded as an accordion-like plastic hose. The accordion-like hose has folds and bends to allow the hose to expand and contract as needed. The use of an expandable, flexible hose allows an air duct to be added to a cooling system without having to modify the existing computer system board layout. The expandable, flexible hose is merely routed around the existing computer system components.

25 In one embodiment, the housing 522 clamps to a heat sink 534. The housing 522 contains and guides air movement through the plurality of fins of the heat sink 534 which is thermally coupled to a processor 536. In one embodiment, the housing air duct adapter 528 and the housing fan adapter 530 function as end caps on the housing 522 to lock the housing in place so that the housing does not move 30 horizontally on the heat sink. The various cooling attachments shown in Figure 5B

are for example purposes only. The apparatus for cooling an electronic device may be formed with additional or differing cooling attachments. For example, in an alternate embodiment, the housing air duct adapter 528, the housing 522, and the housing fan adapter 530 are a single part.

5 Figure 6A is a perspective view of an alternate embodiment of an apparatus which utilizes redundant fans for cooling an electronic device. In one embodiment, the apparatus 600 shown in Figure 6A comprises a housing 602, a first fan 604, a second fan (shown in Figure 6B), and an air duct 608. The air duct 608 directs a flow of air external to the chassis to the housing 602. The housing 602 is adapted to
 10 receive an air duct 608 from the top of the housing. The first fan 604 is coupled to a first end of the housing 602. The second fan is coupled to the second end of the housing. In one embodiment, the first fan 604 and the second fan pull air through the enclosure created by the housing 602 and exhaust the air into a chassis of a computer system. The arrows in Figure 6A indicate that air enters the apparatus 600
 15 through the air duct 608. The air enters the housing 602 in the middle and is exhausted out both sides of the housing 602. As in Figures 5A and 5B, the air duct 608 and the housing 602 channel air through the fins of the heat sink in a manner that substantially reduces blowby.

 Figure 6B is an exploded view of the apparatus shown in Figure 6A. As
 20 shown in Figure 6B, the apparatus 620 for cooling an electronic device is comprised of a top entry housing 622 and various cooling attachments from the kit of parts shown in Figure 3. The various cooling attachments that are assembled to form the apparatus 620 include an air inlet chassis adapter 624, an air duct 626, a first housing fan adapter 628, a first fan 630, a second housing fan adapter 632, and a
 25 second fan 634.

The air inlet chassis adapter 624 is coupled to an opening in the chassis and to the air duct 626. The air duct 626 is also coupled to the housing 622 at the top entry. The first housing fan adapter 628 holds the first fan 630 and is coupled to the housing 622. The second housing fan adapter 632 holds the second fan 634 and is

fan (also not shown). The second fan exhausts heated air from the second housing 808 into the computer system chassis.

The example embodiment shown in Figure 8 provides exhaust fans on each side of a single air intake. This example embodiment allows for different processor configurations than in prior systems. In prior dual processor systems, it was not desirable to have processors in-line with one another because of a shadowing effect. Shadowing refers to effect that occurs when air flows in the same direction over processors in an in-line configuration. When the processors are positioned in-line with one another, heat is dissipated from the first processor into the air flow that is then used to cool the second processor. Prior systems typically staggered the processors to avoid a shadowing effect. However, one of the advantages of some embodiments of an apparatus for cooling an electronic component of the present invention is that multiple processors can be placed in-line with one another. This allows greater flexibility in the design and layout of integrated circuit boards.

In the example embodiment shown in Figure 8, the apparatus for cooling an electronic device 800 is assembled from a two housings and various cooling attachments from the kit of parts shown in Figure 3. In another alternate embodiment, the apparatus shown in Figure 8 can be expanded to cool four processors by using four fans and a single duct entering in the middle of the configuration provided that the duct is large enough to generate enough air flow to adequately cool four processors.

Figure 9 is a perspective view of an alternate embodiment of an apparatus 900 with two processors in an in-line configuration. The apparatus 900 shown in Figure 9 comprises an air intake duct 902 coupled to a housing connector 904. The housing connector 904 couples a first housing 906 fitted over a first processor and a second housing 908 fitted over a second processor. A first housing air duct adapter 910 is coupled to the first housing 906. The first housing air duct adapter 910 is coupled to a first air exhaust duct 912. Likewise, the second housing air duct adapter 912 is coupled to a second air exhaust duct 914. The first air exhaust duct 912 and the second air exhaust duct 914 are coupled to a chassis fan adapter 916.

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The chassis fan adapter 916 allows a system fan (not shown) to be used to exhaust heated air from the first housing 906 and the second housing 908 through the first air exhaust duct 912 and the second air exhaust duct 914 respectively.

5 Figure 10 is a perspective view of a dual processor configuration in which each processor housing is coupled to its own air duct for fresh air intake. In the example embodiment shown in Figure 10, two separate integrated circuit cooling systems are utilized. Each one of the integrated circuit cooling systems comprises a housing, a fan, and an air duct. In one embodiment, each one of the cooling systems are assembled as shown in Figure 5B.

10 An apparatus for dissipating heat from an electronic component according to embodiments of the present invention is not limited to the configurations shown above. Alternate embodiments are contemplated having the interchangeable cooling attachments and one or more housings arranged in a multitude of configurations. Such alternate embodiments include any a means to generate air flow through a plurality of fins of a heat sink. Such alternate embodiments further include any means to contain and guide air movement through the plurality of fins of a heat sink such that the means substantially eliminates blowby. Such alternate embodiment may also include any means to direct air external to a chassis to the means to contain and guide air movement.

20 The example embodiments described above are not shown in a system chassis. However, a processor cooling system according to any of the example embodiments described above may be incorporated into a well know computerized system including a chassis, an integrated circuit board mounted in the chassis, and one or more processors coupled to the integrated circuit board.

25 Furthermore, a system integrator is likely to add a processor cooling system to such a well know computerized system using a kit of parts such as the kit of parts described by reference to Figure 3. In one embodiment, a system integrator performs a method of assembling a cooling system for an integrated circuit by closely coupling a housing to a heat sink for an integrated circuit and by coupling a fan to the housing. The system integrator may also couple one or more cooling

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5 attachments to the housing. One of the advantages of a method of assembling a cooling system using a kit of parts as described herein is that a cooling system can be assembled for use with a variety of industry standard integrated circuit boards from a single kit. The cooling system is assembled by selecting the appropriate cooling attachments based on the space available on the integrated circuit board and the particular thermal situation. The kit also allows the cooling system to be added after the chassis is assembled.

10 In one embodiment, the operation of such a cooling system provides a method of cooling an integrated circuit by generating a flow of external ambient air through an air duct to a housing closely fitted over a heat sink. The method further includes drawing the flow of external ambient air over the heat sink.

15 The example embodiments described above provide a scalable, cost effective, highly efficient, universally applied thermal solution for high heat generating electronic components. In one embodiment, a processor heat sink housing attaches over a heat sink and attaches to a processor socket. Various cooling attachments can be attached to this processor heat sink housing to provide a multitude of flow enhancers. These components also provide commonly available mechanical features that lock the assembly in place. The cooling attachments are designed to provide a thermal engineer with several options for cooling an electronic component. Example embodiments utilizing a "Lego" type set of components that can be placed in multiple configurations provide unique thermal solutions.

20 It is to be understood that the above description is intended to be illustrative, and not restrictive. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

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